

Pu300: A Tool for Measurement of Plutonium Age for Arms Control Transparency via Gamma- Ray Spectroscopy

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Pu300: A Tool for Measurement of Plutonium Age for Arms control Transparency via Gamma-Ray Spectroscopy*

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Abstract:

Pu300 has particular application in the Arms Control Transparency arena, where very sensitive material is often the subject of tests and measurements. In Arms Control Transparency projects, we attempt to measure attributes of material removed from a nuclear weapon without revealing sensitive information about the material. The measured attribute can either be reported directly or compared against a threshold value. The set of attributes that are measured can be used as a fingerprint for the material.

One such attribute for plutonium is material age. Age, in this sense, is defined as the amount of time that has passed since americium separation. The Pu300 system consists of a coaxial HPGe detector and a Canberra Inspector multichannel analyzer. The Inspector allows the high resolution spectral information to be limited by adjusting upper and lower level discriminators so only the information between 330keV and 350keV is collected. The fits of the peaks in the gamma-ray spectrum are fed into a physics code to give an age of the material measured. The physics code is based on the buildup of ^{241}Am from the decay of ^{241}Pu .

Introduction:

Reliable codes such as MGA [1] are often used to analyze plutonium data where a quick analysis will give accurate isotopic composition of a plutonium sample. From this information, the age (or time since Am separation) of the material can be deduced. MGA analyzes gamma rays from the x-ray region of the spectrum which can present limitations, depending on the container holding the source material.

A new code, Pu300, was developed using MGA fitting routines, but Pu300 overcomes the limitations of looking at the x-ray region. Pu300 measures plutonium age by measuring the gamma rays in the 330 keV through 350 keV, which are much more penetrating than x-rays. Hardware thresholds in the Canberra Inspector can be set above and below the region of interest data to eliminate data outside this 20 keV energy range.

Pu300 is particularly useful in Arms Control Transparency measurements, where the plutonium being measured has classified characteristics (i.e. isotopic composition, mass, and shape). In addition, most of the material is sight sensitive; it must be inspected while inside a heavy storage container. Transparency measurements are designed to protect classified information when making measurements of classified material. Properties such as isotopic composition, mass, shape, and age can be inferred from radiation signatures energetic enough to be detected outside heavy storage containers. Such properties build a fingerprint for the plutonium being measured, but age is the only dynamic attribute that will change over time in the fingerprint.

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Method:

Plutonium is a radioactive material that emits gamma rays during decay to its groundstate. The ^{241}Pu in the sample decays to both ^{241}Am and ^{237}U . The ^{241}Am and the ^{237}U both decay to ^{237}Np . This decay is shown in figure 1.

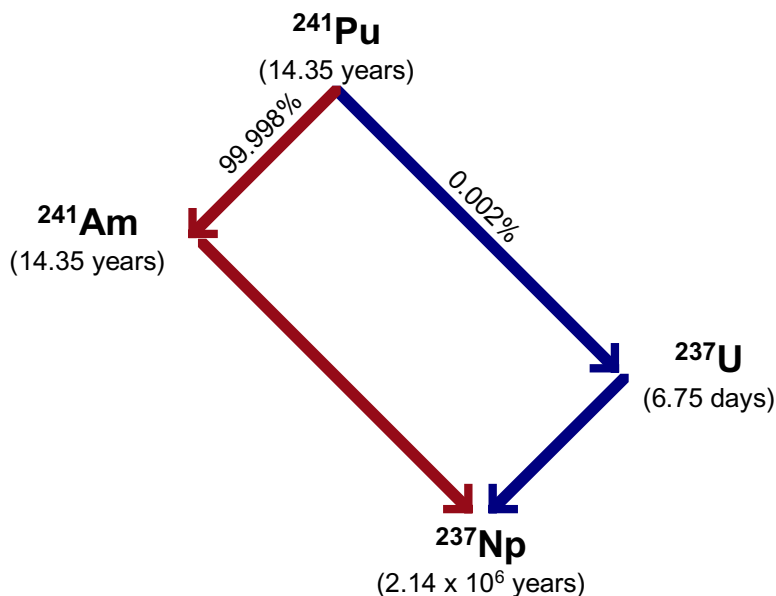


Figure 1. ^{241}Pu Decay

Using the information from figure 1 and knowing the absolute branching ratios, we can determine how quickly ^{241}Am grows into the plutonium sample. This in-growth rate is determined using a simple two step exponential decay formalism.

Age can be determined from different regions of the gamma-ray spectrum: 40, 100, 125 and 300 keV regions. The 300 keV region is the most promising region for transparency measurements of age, since the plutonium will reside in a thick container. The thick container will act as a gamma-ray attenuator that can make the age measurements impossible when using lower energy gamma rays.

Results:

Pu300 has been shown to give excellent results over the region of ages from 8-20 years. These Pu300 measurements were made on sample spectra that were taken for other purposes, i.e. the spectra were not optimized for Pu300. The results (figure 2) are shown as a ratio of age measured by MGA to the age measured by Pu300. A result of 1.00 is a perfect age determination by Pu300.

Pu300 can be used to directly display the age as shown in figure 2 or it can be used in a restricted mode to show that the age is above or below a specified threshold — an important consideration for transparency measurements.

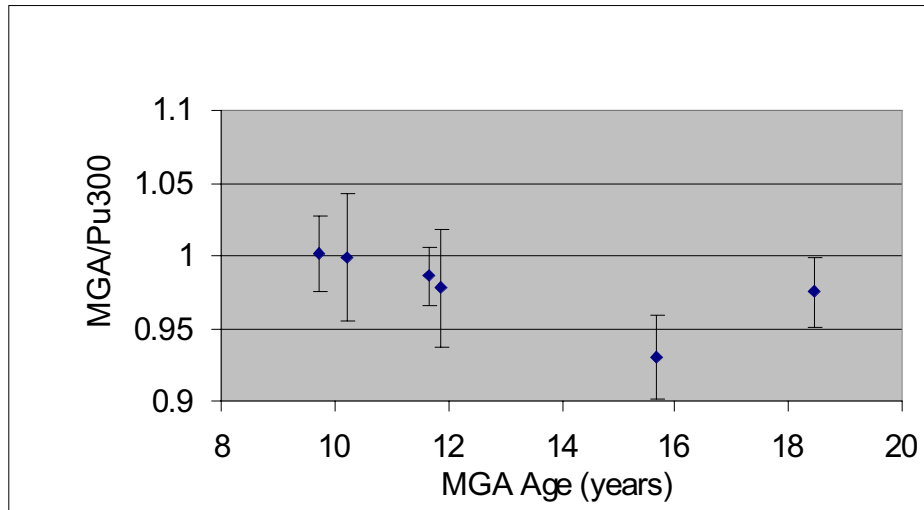


Figure 2: Pu300 Results

Conclusions:

Pu300 is a useful diagnostic for Arms Control Transparency measurements. It allows the reliable use of penetrating gamma rays for making age determination from material in a thick storage container, where other codes that employ radiation signatures from the easily shielded x-ray region of the spectrum might fail. Pu300 has been shown to work in age ranges from 8 to 20 years using only a 20 keV window of information from the plutonium spectrum. Pu300 can give the age information explicitly or compare the measured age to a specified threshold value.

References:

[1] Gunnink, R., UCRL-LR-103220-VOL-1;ISPO-317, Lawrence Livermore National Laboratory, 1990.